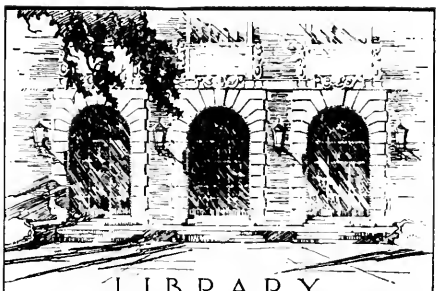

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IMPROVEMENT IN THE CHEMICAL COMPOSITION OF THE CORN KERNEL.

INTRODUCTION.

The many different uses which are made of corn and the enormous value of the crop to the United States in general, and to the state of Illinois in particular, may certainly be deemed sufficient reason for investigating the possibility of making improvements in the chemical composition of this important grain. The nature of any desired improvement will, of course, depend upon the use which is to be made of the crop produced. For example, if corn is grown for the manufacture of starch, glucose-sugar, syrup, or alcohol, it is desirable that the grain contain a high percentage of carbohydrates, and that the percentages of its other chief constituents, protein and fat, should be reduced as much as possible. If corn is to be used as feed for growing animals or manufactured into corn flour for human food, a higher percentage of protein will certainly increase its value. If it is to be used chiefly for fattening stock, perhaps an increased percentage of fat would be an improvement.

That the chemical composition of corn can be changed seems reasonably probable from the changes which have been produced in some other plants,—notably in the sugar beet.

PRELIMINARY STUDY.—Before the work reported in this bulletin could be begun, it was necessary to make a chemical study of the corn plant, and to devise methods for conducting experiments with the object of improving the composition of the grain. It is known that the mineral content of plants can be changed to some extent by the addition to the soil of mineral materials in a form readily available to the plant, but that the temporary change thus effected would have any appreciable hereditary tendency seems very unlikely. The method of procedure which seemed most promising is based upon the common method of making improvement in animals, namely, selecting the best examples of the desired type and breeding successively and under the best conditions from that stock, retaining from each generation only the highest types obtained. This is practically the method by which the sugar content of certain varieties of beets has been increased from less than five per cent. to twelve or even to sixteen per cent. A small portion of a beet is analyzed and, if it is found to be sufficiently rich in sugar, the beet is then set out as a "mother," or seed, beet. From the seed produced beets are grown and another selection of seed beets is made on the basis of their sugar content. But the kernel of corn is not sufficient in quantity to make a complete chemical analysis by any practical method, and certainly the same kernel could not be used for analysis and also for seed.

Early in the year 1896 the writer began a special study of the chemistry of corn. Although, in the latter part of that year, all of the analytical records of the work were destroyed by fire, some valuable knowledge of the subject had been obtained. Among the important facts which the results obtained had indicated were:

1. That the ear of corn is approximately uniform throughout in the chemical composition of its kernels.

2. That there is a wide variation in the chemical composition of different ears of the same variety of corn.

That these conclusions are correct has been fully shown by some more recent work of which the data have already been published in detail in Bulletin No. **53** (see pages 150 to 157).

PLAN OF EXPERIMENTS.—The uniformity of the individual ear of corn makes it possible to determine very approximately the composition of the grain by analyzing a sample consisting of a few rows of kernels. The remainder of the kernels on the ear may then be planted if desired. The wide variation in composition between different ears is a very important factor in the work of selecting seed, as a starting point is thus furnished in each of the several lines of desired improvement. The general plan of the experiments to improve the composition of corn was to make analyses of samples from a large number of ears, select for

seed those ears which were found to contain a high percentage of a desired constituent, plant in an isolated field (to avoid cross fertilization from other corn), and grow the crop under as good field conditions as possible. From the crop obtained a large number of ears are selected, and samples of each ear are analyzed, seed being taken, as before, from those ears which are found to be highest in the percentage of the constituent which it is desired to increase. Each year this process is repeated.

While it may require ten or twenty years' work to enable one to form a very definite opinion as to the extent to which it is possible to influence the chemical composition of corn, it is believed that the data and results thus far obtained may be of practical and scientific interest.

General Explanations.—All work reported in this bulletin was done upon a single variety of corn, commonly known as Burr's White. It has been grown for several years by this Station with precautions to keep the variety pure and distinct.

The analytical methods employed have been described in detail in Bulletins **43** and **53** of this Station. They are based upon the methods of the Association of Official Agricultural Chemists.

By the term *ash* is meant the mineral matter which remains after the organic matter is burned.

Protein consists of the nitrogenous organic matter. It is the chief constituent necessary to the growth and repair of the animal body.

The *fat* is the material extracted from corn by ether. It is practically pure corn oil.

The *carbohydrates* consist chiefly of starch, but include also the small amounts of other allied substances found in corn, as sugar, fiber, and pentosans.

Unless otherwise stated, all results are reported on the basis of dry matter, or water-free substance.

For more complete explanations of technical terms, or information concerning the uses of food constituents, the reader is referred to the appendix to Bulletin No. **43**.

SELECTION OF SEED CORN BY ANALYSIS.

From the 1896 crop of Burr's White corn grown upon the Experiment Station farm, two bushels (163 ears) of good, sound ear corn suitable for seed were taken. From each ear a sample consisting of three rows of kernels, lengthwise of the ear, was taken for analysis. The data obtained from the analysis of the one hundred sixty-three samples appear in Table 1.

TABLE 1. COMPOSITION OF CORN FROM ONE HUNDRED SIXTY-THREE DIFFERENT EARS.

Corn No.	Ash.	Protein.	Fat.	Carbo-hydrates.	Corn No.	Ash.	Protein.	Fat.	Carbo-hydrates.
76	1.70	10.05	4.77	83 48	131	1.47	10.49	4.86	83 18
77	1.45	10.42	5.24	82.89	132	1.55	11.13	4.55	82.77
78	1.55	11.00	4.90	82.55	133	1.39	11.13	4.10	83.38
79	1.62	10.89	4.88	82.61	134	1.30	10.85	4.45	83.40
80	1.63	11.50	4.58	82.29	135	1.37	11.29	4.53	82.81
81	1.47	11.49	4.26	82.78	136	1.59	11.43	5.10	81.88
82	1.39	11.78	4.83	82.00	137	1.47	11.61	4.41	82.51
83	1.17	9.08	4.05	85.70	138	1.36	11.36	4.53	82.75
84	1.51	12.79	4.25	81.45	139	1.57	9.81	5.23	83.39
85	1.46	11.76	4.94	81.84	140	1.34	10.53	4.18	83.95
86	1.50	12.07	4.61	81.82	141	1.45	12.42	4.51	81.62
87	1.59	12.40	4.74	81.27	142	1.37	9.31	4.82	84.50
88	1.35	9.34	4.84	84.47	143	1.29	11.33	4.49	82.89
89	1.61	10.71	4.70	82.98	144	1.42	11.39	4.99	82.20
90	1.55	9.90	4.97	83.58	145	1.45	8.25	4.81	85.49
91	1.56	10.68	4.91	82.85	146	1.47	11.29	4.83	82.41
92	1.46	12.96	3.97	81.61	147	1.26	12.21	4.49	82.04
93	1.48	11.80	4.80	81.92	148	1.54	11.94	4.74	81.78
94	1.74	11.89	4.55	81.82	149	1.36	11.29	4.08	83.27
95	1.55	10.49	5.51	82.45	150	1.44	11.71	4.03	82.82
96	1.60	11.10	4.38	82.92	151	1.40	9.31	4.96	84.33
97	1.59	11.84	4.96	81.61	152	1.41	11.90	4.09	82.60
98	1.39	10.23	5.51	82.87	153	1.35	12.51	5.19	80.95
99	1.42	8.40	4.91	85.27	154	1.42	11.13	5.02	82.43
100	1.65	12.28	4.76	81.31	155	1.44	11.05	4.53	82.98
101	1.30	10.08	4.86	83.76	156	1.39	11.74	4.14	82.73
102	1.49	11.83	4.51	82.17	157	1.46	10.02	4.88	83.64
103	1.44	11.25	4.78	82.53	158	1.45	10.66	4.51	83.38
104	1.54	11.82	4.43	82.21	159	1.48	11.53	4.65	82.34
105	1.37	12.36	4.84	81.43	160	1.43	11.50	4.83	82.24
106	1.33	11.15	5.21	82.31	161	1.47	11.11	4.93	82.49
107	1.33	9.47	4.97	84.23	162	1.48	12.09	5.61	80.82
108	1.30	11.04	4.67	82.99	163	1.29	10.78	5.09	82.84
109	1.45	10.82	5.65	82.08	164	1.30	9.36	4.34	85.00
110	1.60	12.81	5.21	80.38	165	1.47	10.50	4.75	83.28
111	1.31	10.76	4.13	83.80	166	1.65	11.29	3.84	83.22
112	1.26	10.48	4.54	83.72	167	1.37	9.58	4.72	84.33
113	1.10	9.30	4.38	85.22	168	1.49	10.94	4.34	83.23
114	1.33	9.12	4.10	85.45	169	1.60	11.79	4.22	82.39
115	1.29	10.41	4.17	84.13	170	1.36	11.06	4.39	83.19
116	1.10	8.38	4.88	85.64	171	1.44	11.18	5.75	81.63
117	1.42	9.95	4.23	84.40	172	1.45	12.28	3.99	82.28
118	1.44	11.40	5.02	82.14	173	1.39	10.14	4.35	84.12
119	1.55	12.38	4.62	81.45	174	1.30	10.19	5.22	83.29
120	1.39	9.97	4.42	84.22	175	1.40	12.68	5.29	80.63
121	1.36	10.09	4.82	83.73	176	1.37	9.86	4.73	84.04
122	1.36	10.31	5.25	83.08	177	1.48	13.06	4.93	80.53
123	1.34	9.68	4.01	84.97	178	1.37	10.93	4.76	82.94
124	1.44	11.87	4.61	82.08	179	1.32	11.87	5.03	81.78
125	1.34	10.73	4.53	83.40	180	1.39	11.27	4.55	82.79
126	1.49	13.87	5.72	78.92	181	1.47	9.66	4.21	84.66
127	1.43	11.53	4.31	82.73	182	1.37	10.97	3.94	83.72
128	1.33	11.64	4.57	82.46	183	1.54	10.32	5.46	82.68
129	1.36	11.25	4.16	83.23	184	1.44	10.68	4.89	82.99
130	1.35	11.86	5.01	81.78	185	1.42	9.33	4.49	84.76

TABLE 1. *Continued.*

Corn No.	Ash.	Protein.	Fat.	Carbohydrates.	Corn No.	Ash.	Protein.	Fat.	Carbohydrates.
186	1.48	10.78	4.74	83.00	213	1.53	12.40	4.75	81.32
187	1.28	10.49	4.44	83.79	214	1.58	10.22	4.43	83.77
188	1.53	13.10	5.51	79.86	215	1.45	9.22	4.60	84.73
189	1.32	9.58	5.63	83.47	216	1.42	10.27	4.35	83.96
190	1.25	11.50	4.95	82.30	217	1.32	9.39	4.83	84.46
191	1.29	11.19	4.31	83.21	218	1.40	9.74	4.71	84.15
192	1.51	11.49	4.07	82.93	219	1.37	9.92	4.32	84.39
193	1.36	9.47	4.51	84.66	220	1.43	9.63	5.23	83.71
194	1.50	11.47	4.65	82.38	221	1.32	10.33	5.01	83.34
195	1.54	11.09	4.37	83.00	222	1.41	12.34	4.57	81.68
196	1.30	9.44	3.95	85.31	223	1.49	10.58	4.64	83.29
197	1.26	11.20	4.46	83.08	224	1.52	11.36	4.63	82.49
198	1.44	10.23	4.53	83.80	225	1.33	9.15	4.55	84.97
199	1.29	10.64	4.67	83.40	226	1.36	10.31	5.08	83.25
200	1.39	10.13	4.84	83.64	227	1.46	12.63	5.15	80.76
201	1.38	9.64	5.22	83.76	228	1.41	12.16	4.12	82.31
202	1.39	11.26	4.96	82.39	229	1.36	11.04	4.52	83.08
203	1.26	10.48	4.59	83.67	230	1.43	12.10	4.29	82.18
204	1.66	12.57	4.82	80.95	231	1.33	10.95	4.60	83.12
205	1.46	10.71	5.36	82.47	232	1.52	12.76	4.10	81.62
206	1.34	10.27	4.65	83.74	233	1.40	9.75	4.14	84.71
207	1.25	11.09	4.27	83.39	234	1.39	10.78	4.76	83.07
208	1.48	12.05	4.78	81.69	235	1.58	9.97	5.27	83.18
209	1.48	10.22	4.30	84.00	236	1.40	10.18	6.02	82.40
210	1.45	11.16	4.75	82.64	237	1.47	11.16	5.13	82.24
211	1.48	10.44	4.21	83.87	238	1.60	11.42	5.20	81.78
212	1.27	9.75	4.12	84.86					

Plans were made to carry on four separate experiments to change the chemical composition of corn: 1. To increase the protein content. 2. To decrease the protein content. 3. To increase the fat content. 4. To decrease the fat content. It is of course manifest that, if the percentages of protein and fat are increased, the percentage of carbohydrates is decreased, and *vice versa*. From the lot of one hundred sixty-three ears, four different sets of seed corn were selected on the basis of chemical composition.

1. A set of twenty-four ears whose percentage of protein was comparatively high.

2. A set of twelve ears each of which contained a low percentage of protein.

3. A set of twenty-four ears high in fat content.

4. A set of twelve ears low in fat content.

OUTLINE OF EXPERIMENTS.

In the spring of 1897 the four sets of corn which had been selected were planted on four different fields, or plots, each of which was fairly well isolated from other corn fields in order to avoid cross fertilization by corn of different chemical composition. For convenience these four plots are called: 1. High-protein plot. 2. Low-protein plot. 3. High-fat plot. 4. Low-fat plot. Invariably the seed planted in each row was all taken from a single ear; so that the high-protein plot, for example, contained twenty-four rows planted with seed from the twenty-four ears selected for that purpose.

In the high-protein and high-fat plots the seed containing the very highest percentage of the desired constituent was planted in the middle rows, the remainder of the seed being planted in approximately uniform gradation to either side. In the low-protein and low-fat plots the seed containing the very lowest percentages of protein and fat, respectively, was planted in the middle rows. This arrangement may be clearly seen by referring to the tables.

By planting plots of both high-protein and low-protein corn, or of both high-fat and low-fat corn, results may be obtained which show the influence of selected seed, as independent and distinguishable from the effects due to the influence of the season.

The plots were given ordinary cultivation, and a good crop of corn was grown on each. When the corn was harvested a set of ten good ears was selected from each row, excepting from some outer rows. From some of the middle rows duplicate sets of ten ears each were taken from the same row, as will be seen from the tables, the analytical data from such rows being given in duplicate in all cases. Two rows of kernels (lengthwise of the ear) were taken from each of the ten ears and mixed to form a composite sample to represent the good corn grown on each row.

EXPERIMENTS TO INFLUENCE THE PROTEIN CONTENT OF CORN.

The results from the experiments to change the percentage of protein in corn will be first considered. The tables are arranged to show the percentage of protein in the dry matter of the seed planted and the crop produced. For reference, the Station laboratory serial numbers of all samples analyzed are also given (see Tables 2 and 3).

TABLE 2.—PROTEIN IN CORN PLANTED AND HARVESTED ON HIGH-PROTEIN PLOT IN 1897.

Plot row No.	Corn planted.		Corn harvested		Plot row No.	Corn planted		Corn harvested.	
	Corn No.	Protein, per cent.	Corn No.	Protein, per cent.		Corn No.	Protein, per cent	Corn No.	Protein, per cent.
1	94	**11.89**	270	**9.61**	14	177	**13.06**	345	**10.89**
2	86	**12.07**	275	**11.07**				350	**10.67**
3	230	**12.10**	280	**10.94**	15	188	**13.10**	355	**10.34**
4	213	**12.40**	285	**11.48**				360	**11.48**
5	100	**12.28**	290	**10.85**	16	232	**12.76**	365	**11.05**
6	119	**12.38**	295	**11.64**	17	87	**12.40**	370	**10.75**
7	227	**12.63**	300	**11.46**	18	204	**12.57**	375	**10.86**
8	153	**12.51**	305	**11.57**	19	105	**12.36**	380	**11.07**
9	175	**12.68**	310	**11.17**	20	141	**12.42**	385	**10.88**
10	84	**12.79**	315	**11.14**	21	172	**12.28**	390	**11.73**
11	110	**12.81**	320	**11.16**	22	222	**12.34**	395	**10.76**
12	126	**13.87**	325	**11.60**	23	147	**12.21**	400	**11.30**
			330	**11.31**	24	208	**12.05**	405	**11.53**
13	92	**12.96**	335	**11.07**					
			340	**11.44**	Plot averages		**12.54**	.....	**11.10**

TABLE 3 —PROTEIN IN CORN PLANTED AND HARVESTED ON LOW-PROTEIN PLOT IN 1897.

Plot row No.	Corn planted.		Corn harvested.		Plot row No.	Corn planted.		Corn harvested.	
	Corn No.	Protein, per cent.	Corn No.	Protein, per cent.		Corn No.	Protein, per cent.	Corn No.	Protein, per cent.
1	151	**9.31**							
2	114	**9.12**	410	**10.55**	7	99	**8.40**	440	**10.36**
3	83	**9.08**	415	**10.89**	8	215	**9.22**	445	**10.20**
4	225	**9.15**	420	**10.26**	9	185	**9.33**	450	**9.89**
5	116	**8.38**	425	**10.10**	10	164	**9.36**	455	**10.24**
6	145	**8.25**	430	**10.73**	11	113	**9.30**	460	**11.20**
			435	**9.90**	12	193	**9.47**	465	**12.24**
Plot averages.							**9.03**	.....	**10.55**

It is observed that the average composition of the corn from the high-protein plot shows a protein content of 11.10 per cent.; while 10.55 is the average percentage of protein in the corn from the low-protein plot, indicating that the difference, .55 per cent., may be ascribed to the influence of the seed selection. On account of the plan, or order, in which the seed corn was arranged in the plots, that is, with the corn of highest protein content in the central rows of the high-protein plot, and the corn of lowest protein content in the central rows of the low-protein plot, we might expect to find a somewhat wider average difference in protein content if we consider only the corn grown on the central half of each plot. From rows 7 to 18 of the high-protein plot we find the average protein content of the corn produced to be 11.12 per cent., while 10.21 is the average percentage of protein in the

corn from rows 4 to 9 of the low-protein plot, thus showing an average difference of .91 per cent.

From each set of ten ears from the 1897 crop, four of those which appeared most suitable for seed corn were reserved for further use. These amounted to one hundred twelve ears from the high-protein plot and forty-eight ears from the low-protein plot. From each of these ears a sample consisting of three or four rows of kernels was taken for analysis, only protein and dry matter being determined. Tables 4 and 5 give the percentage of protein in the dry matter of these samples. The laboratory numbers of these samples of single ears afford ready reference to the row of the plot in which they grew and to the seed from which they were grown. Thus, to each four ears are given the four numbers immediately following the number given to the composite sample of ten ears from the same row. For example, the composite sample from ten ears from row 1, high-protein plot, 1897, is given No. 270, as will be seen by reference to Table 2; and the four samples of single ears from the same row are numbered 271, 272, 273, and 274 (Table 4). Table 2 also shows that these ears grew from corn No. 94, which contained 11.89 per cent. of protein in the dry matter; so that the complete pedigree of each ear is kept from the beginning of these experiments.

While, as has already been shown, the protein content of corn from the high-protein plot averages higher than that from the low-protein plot, attention is called to the wide variation in the percentage of protein in corn from different ears grown in a single season, in the same plot of ground, and from seed of nearly uniform protein content. This is especially marked in the ears from the low-protein plot (Table 5). For example, corn No. 458 contains 8.22 per cent. of protein and grew from seed No. 185 which contained 9.33 per cent. of protein; while corn No. 466 contains 13.98 per cent. of protein and grew from seed No. 113 whose protein content was 9.30 per cent.

Of course the pedigree of the individual ears used for seed in 1897 was not known, and possibly some variations may be due to hereditary influences, but it seems probable that the wide variations are caused principally by local differences of soil conditions. Some efforts to obviate this difficulty are discussed farther on.

In order to retain hereditary influences the seed for the high-protein plot for 1898 was all selected from corn which grew from seed of high protein content the previous year. On this account corn with high protein content from the low-protein plot was rejected for seed. Likewise seed for 1898 for the low-protein plot was selected only from corn which grew upon that plot in 1897.

TABLE 4.—PROTEIN IN SAMPLES OF ONE HUNDRED TWELVE EARS OF CORN GROWN ON HIGH-PROTEIN PLOT IN 1897.

Corn No.	Protein, per cent.	Corn No.	Protein, per cent.	Corn No.	Protein, per cent.	Corn No.	Protein, per cent.
271	8.82	306	12.33	341	11.65	376	10.47
272	8.42	307	12.39	342	11.35	377	10.92
273	11.60	308	9.64	343	10.60	378	9.32
274	8.34	309	9.93	344	12.16	379	12.28
276	12.83	311	10.65	346	11.63	381	9.31
277	10.46	312	11.05	347	12.26	382	11.00
278	9.95	313	9.89	348	8.76	383	12.23
279	10.96	314	10.22	349	10.69	384	11.99
281	12.62	316	11.08	351	11.39	386	12.10
282	10.43	317	10.29	352	10.59	387	9.20
283	9.87	318	11.72	353	9.65	388	9.76
284	11.58	319	8.76	354	9.83	389	9.18
286	10.97	321	11.43	356	8.63	391	12.46
287	11.08	322	10.94	357	11.08	392	11.14
288	10.23	323	11.18	358	11.39	393	10.03
289	12.99	324	11.55	359	9.12	394	13.27
291	11.52	326	13.62	361	11.63	396	9.94
292	10.44	327	10.99	362	9.98	397	11.78
293	11.92	328	11.07	363	10.45	398	11.30
294	11.25	329	9.18	364	11.89	399	11.08
296	11.11	331	11.40	366	12.01	401	11.23
297	12.07	332	12.24	367	9.51	402	10.92
298	13.58	333	10.06	368	11.43	403	9.72
299	11.68	334	11.02	369	11.76	404	11.14
301	10.80	336	10.78	371	11.75	406	10.44
302	12.26	337	11.28	372	9.46	407	12.72
303	11.20	338	11.09	373	11.17	408	12.80
304	11.97	339	12.85	374	8.67	409	11.17

TABLE 5.—PROTEIN IN SAMPLES OF FORTY-EIGHT EARS OF CORN GROWN ON LOW-PROTEIN PLOT IN 1897.

Corn No.	Protein, per cent.	Corn No.	Protein, per cent.	Corn No.	Protein, per cent.	Corn No.	Protein, per cent.
411	11.37	426	11.46	441	10.25	456	10.16
412	11.47	427	8.29	442	10.28	457	10.22
413	11.36	428	10.19	443	11.40	458	8.22
414	11.15	429	9.69	444	9.34	459	11.92
416	8.88	431	10.98	446	8.84	461	11.61
417	9.26	432	9.67	447	11.27	462	10.85
418	11.62	433	9.91	448	9.05	463	10.04
419	10.43	434	12.85	449	8.95	464	11.68
421	9.60	436	9.38	451	10.80	466	13.98
422	9.93	437	10.03	452	10.07	467	12.55
423	12.45	438	10.97	453	12.13	468	13.89
424	10.43	439	9.28	454	10.04	469	12.19

In planting the corn in 1898, the same general plan of the previous year was followed. Good crops of corn were grown. Sets of ten ears each were taken from each row, duplicate sets being taken from some rows, as will appear in the tables. Composite samples to represent each row were made, as before, by taking two rows of kernels from each of the ten ears.

Tables 6 and 7 give the percentage of protein in the seed planted and in the crop produced in each row of the plots.

TABLE 6. PROTEIN IN CORN PLANTED AND HARVESTED ON HIGH-PROTEIN PLOT IN 1898.

Plot row No.	Corn planted.		Corn harvested.		Plot row No.	Corn planted.		Corn harvested.	
	Corn No.	Protein, per cent.	Corn No.	Protein, per cent.		Corn No.	Protein, per cent.	Corn No.	Protein, per cent.
1	384	**11.99**	820	**11.18**	13	298	**13.58**	960	**11.74**
2	366	**12.01**	830	**10.86**				970	**11.42**
3	386	**12.10**	840	**10.64**	14	289	**12.99**	980	**11.42**
4	347	**12.26**	850	**11.26**				990	**11.20**
5	332	**12.24**	860	**11.61**	15	276	**12.83**	1000	**11.34**
6	306	**12.33**	870	**11.24**	16	407	**12.72**	1010	**10.77**
7	391	**12.46**	880	**11.26**	17	307	**12.39**	1020	**11.03**
8	281	**12.62**	890	**10.80**	18	379	**12.28**	1030	**10.96**
9	408	**12.80**	900	**10.55**	19	302	**12.26**	1040	**10.47**
10	339	**12.85**	910	**10.92**	20	344	**12.16**	1050	**10.33**
11	394	**13.27**	920	**11.06**	21	383	**12.23**	1060	**11.58**
			930	**10.67**	22	297	**12.07**	1070	**9.78**
12	326	**13.62**	940	**11.17**	23	304	**11.97**	1080	**10.72**
			950	**12.48**	24	364	**11.89**	1090	**10.95**
Plot averages							**12.49**	....	**11.05**

TABLE 7. PROTEIN IN CORN PLANTED AND HARVESTED ON LOW-PROTEIN PLOT IN 1898.

Plot row No.	Corn planted.		Corn harvested.		Plot row No.	Corn planted.		Corn harvested.	
	Corn No.	Protein, per cent.	Corn No.	Protein, per cent.		Corn No.	Protein, per cent.	Corn No.	Protein, per cent.
1	421	**9.60**	1100	**10.92**	7	427	**8.29**	1170	**10.43**
2	444	**9.34**	1110	**11.00**				1180	**11.14**
3	417	**9.26**	1120	**11.03**	8	416	**8.88**	1190	**10.68**
4	449	**8.95**	1130	**10.06**	9	448	**9.05**	1200	**11.16**
5	446	**8.84**	1140	**9.83**	10	439	**9.28**	1210	**9.93**
6	458	**8.22**	1150	**10.26**	11	436	**9.38**	1220	**10.27**
			1160	**10.19**	12	432	**9.67**	1230	**10.83**
Plot averages							**9.06**	.....	**10.55**

It will be seen that the average protein content of the corn from the high-protein plot for 1898 is 11.05 per cent. while 10.55 is the aver-

age percentage from the low-protein plot, making a difference of .50 per cent. The difference between the averages becomes .70 per cent. if we consider only the central half of each plot. These results are nearly the same as obtained in 1897.

In order to avoid local differences in soil conditions, another plot of ground was planted in 1898 with corn of known protein content. For want of a better name this is called the "Mixed-protein Plot." It contained five rows of ten hills each, or fifty hills. In each hill were planted four kernels of corn of which two were high and two were low in protein content. The kernels were so arranged in the hill that the stalk of corn produced by each could be known. When the crop was harvested eight to ten ears from both the high-protein seed and the low-protein seed were taken from each row. By taking two rows of kernels from each ear ten composite samples were made of which five represent the corn grown in the five rows from high-protein seed, and the other five represent the corn produced in the same rows from low-protein seed.

Table 8 shows the protein content of the seed planted and of the samples taken from the crop harvested.

TABLE 8. PROTEIN IN CORN PLANTED AND HARVESTED ON MIXED-PROTEIN PLOT IN 1898.

Plot row No	Corn planted.		Corn harvested		Corn planted.		Corn harvested.	
	Corn No.	Protein, per cent.	Corn No.	Protein, per cent.	Corn No.	Protein, per cent.	Corn No.	Protein, per cent.
1	408	**12.80**	698	**11.24**	446	**8.84**	697	**9.72**
2	326	**13.62**	700	**11.75**	458	**8.22**	699	**11.04**
3	407	**12.72**	702	**12.10**	427	**8.29**	701	**10.09**
4	304	**11.97**	704	**11.65**	416	**8.88**	703	**10.89**
5	364	**11.89**	706	**11.81**	448	**9.05**	705	**10.58**
Plot averages.....				**11.71**	.....		.....	**10.46**

The results show that in every row the high-protein seed produced corn with a higher protein content than that produced by the low-protein seed. The average protein content of the corn from the high-protein seed is 11.71 per cent., while 10.46 is the average percentage of protein in the corn from the low-protein seed. This makes an average difference of 1.25 per cent.

In order to obtain more detailed information from this plot, twenty-two pairs of ears were taken from twenty-two hills, one ear from each pair having grown from high-protein seed and the other from low-protein seed. The protein in the corn from each ear was determined, and the results are given in Table 9.

TABLE 9. PROTEIN IN CORN FROM FORTY-FOUR EARS GROWN ON THE MIXED-PROTEIN PLOT IN 1898.

Hill No.	From high-protein seed.		From low-protein seed.		Hill No.	From high-protein seed.		From low-protein seed.	
	Corn No.	Protein, per cent.	Corn No.	Protein, per cent.		Corn No.	Protein, per cent.	Corn No.	Protein, per cent.
1	708	**8.89**	707	**10.68**	12	730	**12.12**	729	**9.96**
2	710	**9.11**	709	**8.03**	13	732	**12.20**	731	**12.06**
3	712	**10.17**	711	**10.38**	14	734	**8.85**	733	**9.82**
4	714	**9.88**	713	**10.42**	15	736	**11.55**	735	**10.23**
5	716	**11.64**	715	**9.45**	16	738	**11.56**	737	**11.19**
6	718	**12.28**	717	**8.64**	17	740	**11.49**	739	**8.63**
7	720	**11.23**	719	**9.34**	18	742	**10.04**	741	**10.49**
8	722	**12.39**	721	**10.21**	19	744	**9.33**	743	**7.99**
9	724	**12.39**	723	**10.68**	20	746	**13.55**	745	**9.14**
10	726	**10.23**	725	**8.73**	21	748	**11.49**	747	**14.81**
11	728	**12.24**	727	**11.32**	22	750	**11.73**	749	**11.16**
Averages							**11.11**	....	**10.15**

The average protein content of the twenty-two ears from high-protein seed is 11.11 per cent., while 10.15 is the average percentage found in the ears grown from low-protein seed, showing a difference of .96 per cent. to be attributed to the influence of the seed selection. In six of the twenty-two pairs the ear from low-protein seed contains more protein than the ear from high-protein seed, these six differences varying from .21 per cent. in hill 3 to 3.32 per cent. in hill 21. In sixteen hills the variation follows the order of the seed, the greatest difference being 4.41 per cent. in hill 20. It should be stated that owing to cross fertilization no seed corn was selected from this plot. Table 9 offers some good illustrations of the wide variation in the chemical composition of different ears of corn grown from seed of the same variety, of the same composition, during the same season, and in the same soil. Compare, for instance, the corn grown in hills 20 and 21. The corn from high-protein seed shows a difference of 2.06 per cent. of protein in favor of hill 20, while the corn from low-protein seed is 5.67 per cent. higher in protein in hill 21. Between hills 19 and 21 a difference of soil is indicated by all results obtained, and the corn from the high-protein seed is only 2.16 per cent. higher in protein in hill 21 than in hill 19, while a difference of 6.82 per cent. appears in the corn from the low-protein seed.

It is evident that this apparent individuality of each particular corn plant will admit of much further study. The most probable explanation which has occurred to the writer is, that the roots of the plant which produces the corn of highest protein content push into the surrounding soil somewhat in advance of the roots of the other plants in

the hill and are thus enabled to take up the larger part of the available supply of nitrogen. However, the marked differences frequently observed among different animals of exactly the same breeding lead one to question if the variation in the supply of food materials will entirely explain this individuality of the corn plant. Incidentally it may be stated that the writer has found different ears of good sound Burr's White corn varying from 7.50 to 16.11 per cent. of protein in the dry matter. The fact that one good ear of corn has been produced with a protein content above 16 per cent. is a promise of the possibility of improving corn in that direction. This belief is strengthened by the experimental results thus far obtained at this Station. A summary of these results will be found at the end of this bulletin.

In Bulletin No. **53**, pages 138–141, are quoted some results of combined chemical and mechanical study of the corn kernel. These results show that the protein in the corn kernel is contained principally in the glutenous layer surrounding the main body of the kernel. This layer is very thin at the crown of the kernel, but quite thick at the sides. The germ, in the center of the tip end of the kernel is also rich in protein, although the entire germ constitutes only about 12 per cent. of the kernel. The starchy portion, lying between the germ and the glutenous layer and occupying also the center of the crown end of the kernel, consists almost entirely of carbohydrates, although the glutenous layer contains also a large percentage of carbohydrates.

On the basis of this knowledge of the general structure of the corn kernel and chemical composition of its several parts, the writer has made some investigations as to the possibility of selecting corn of high protein content and of low protein content by purely mechanical means, and has found that such a method is both possible and practicable.

By making cross sections and longitudinal sections of several kernels from an ear of corn, one can judge with a very satisfactory degree of accuracy whether the corn is rich or poor in protein. The illustration (Fig. 1) here shown was made from a photograph taken of the corn kernels and sections with a magnification of three diameters. At the left are two sections and a whole kernel from corn No. 945, containing 14.92 per cent. of protein. The sections and whole kernel at the right are from corn No. 1104, containing 7.76 per cent. of protein. About one-fourth of the kernel was cut off from the tip end in making the cross sections. In the longitudinal sections the tip end of the kernel points upward to the right. It will be seen that in the cross sections the white, starchy layer nearly disappears in the high-protein corn but becomes very prominent in the low-protein corn. In the longitudinal sections this difference is also apparent, the white starch in the high-

Corn No.....	945	1104
Protein, per cent...	**14.92**.....	....**7.76**

FIGURE 1.

protein corn being confined almost entirely to the crown end of the kernel, while in the low-protein corn it extends into the tip end in considerable amount. The germ in the high-protein corn is somewhat larger. This is also indicated by the depressions in the whole kernels.

As an experiment a number of ears of both high and low content of protein were mixed together and then separated by mechanical examination. It was found that by examining only one or two kernels from each ear the separation could be made with very few errors.

In order to make a more practical test three hundred eighteen ears of corn were examined. The protein content of the ears in the entire lot did not vary as much as would ordinarily be the case, because thirty-four of the ears highest in protein and twenty-six of those lowest in protein had already been removed from this lot of corn. From what

remained, however, eighteen ears were picked out by mechanical examination as possessing the physical characteristics which indicate a comparatively high content of protein, fifteen ears which appeared to be low in protein being selected at the same time. Table 10 shows the results in detail, the percentage of protein in the corn from each ear being given as previously determined by chemical analysis.

TABLE 10. ACTUAL PROTEIN CONTENT OF CORN SELECTED BY MECHANICAL EXAMINATION.

Ear No.	Corn selected for		Ear No.	Corn selected for		Ear No.	Corn selected for	
	High protein.	Low protein.		High protein.	Low protein		High protein.	Low protein.
	Per cent.	Per cent.		Per cent	Per cent.		Per cent.	Per cent.
1	**11.47**	**11.48**	7	**11.64**	**9.11**	13	**11.87**	**11.27**
2	**12.04**	**9.06**	8	**11.22**	**10.25**	14	**10.21**	**9.36**
3	**9.69**	**9.90**	9	**11.97**	**8.63**	15	**11.71**	**10.25**
4	**11.78**	**9.15**	10	**11.94**	**9.63**	16	**11.59**	
5	**11.65**	**9.67**	11	**10.96**	**8.61**	17	**12.31**	
6	**11.38**	**10.11**	12	**10.83**	**10.95**	18	**10.54**	
Averages.....							**11.38**	**9.83**

The average protein content of the eighteen ears selected for high-protein corn is 11.38 per cent., while 9.83 is the average percentage of protein in the fifteen ears selected for low-protein corn. Only one ear (No. 3) selected for high-protein corn contains less than 9.83 per cent., and a single ear (No. 1) also selected for low protein corn contains more than 11.38 per cent.

Table 11 shows the results obtained in picking out corn by mechanical examination from a lot which contained corn of only very high or very low protein content.

TABLE 11. ACTUAL PROTEIN CONTENT OF CORN SEPARATED BY MECHANICAL EXAMINATION.

Ear No.	Corn selected for		Ear No.	Corn selected for		Ear No.	Corn selected for	
	High protein.	Low protein.		High protein	Low protein.		High protein.	Low protein.
	Per cent.	Per cent.		Per cent.	Per cent.		Per cent.	Per cent.
1	**13.03**	**13.46**	6	**12.83**	**12.39**	11	**12.78**	**8.32**
2	**12.88**	**8.82**	7	**13.25**	**8.57**	12	**12.97**	**7.85**
3	**14.92**	**13.05**	8	**12.98**	**9.02**	13	**13.04**	**8.58**
4	**14.05**	**8.95**	9	**13.04**	**7.85**	14	**16.08**	**7.50**
5	**12.97**	**7.76**	10	**12.82**	**8.29**	15	**12.30**	**8.62**

It will be seen that no errors were made in selecting corn of high protein content, while three mistakes occurred in picking out low-protein corn. It may be stated, however, that these separations were commonly made upon the examination of but one kernel from each ear, and in no case were more than two kernels from an ear examined.

The examination consists in simply cutting cross sections and longitudinal sections from the kernels with a pocket knife and judging as to the combined amount of glutenous layer and germ in relation to the quantity of the white starchy matter, the observation being made with the naked eye. Some difficulties are met in attempting to form a correct opinion as to whether a kernel is rich or poor in protein. For instance, the disposition of the white starchy matter is not strictly uniform in all kernels. It sometimes happens that the tip end of the kernel contains but very little white starch and a cross section near that end would indicate a high protein content, but at the crown end there may be an excessive proportion of starch and the kernel as a whole be low in protein. For this reason it is important that both cross sections and longitudinal sections be made before judgment is taken. Another difficulty is caused by the great variation in the size of kernels of corn from different ears. A very large kernel, for example, may show a considerable quantity of white starch, extending even to the tip of the kernel, and yet contain a high percentage of protein.

In making the selections given in Tables 10 and 11, the time given to each ear was about a half minute, and it is not assumed that the writer possesses any special skill in judging the comparative sizes of small areas or surfaces, the chief point involved in making these examinations. Indeed, it seems but fair to suppose that the average corn grower could, with some practice and care, make a better selection. In fact, the selections here shown were made upon material which was at hand and for the purpose of showing the feasibility of the method, rather than the extent to which it may be carried.

The question whether the size of the corn kernel bears any special relation to the percentage of protein it contains was investigated. Tables 12 and 13 give the average weights in grams of the air-dry kernels from forty different ears which were used in 1899 as seed for the high-protein and low-protein plots. The percentage of protein in the dry matter is also shown.

TABLE 12. AVERAGE WEIGHTS OF KERNELS FROM TWENTY-FOUR EARS OF HIGH-PROTEIN CORN.

Ear No.	Corn No.	Kernel, ave. wt.	Protein, per cent.	Ear No.	Corn No.	Kernel, ave wt.	Protein, per cent.
1	1045	.470	12.35	13	951	.410	14.25
2	1039	.290	12.39	14	895	.330	13.46
3	851	.355	12.48	15	962	.400	13.25
4	1096	.370	12.74	16	984	.430	13.12
5	826	.390	12.83	17	864	.310	13.04
6	961	.340	12.97	18	1011	.405	12.99
7	1062	.395	13.03	19	976	.320	12.98
8	845	.440	13.05	20	1004	.420	12 88
9	953	.355	13.21	21	871	.375	12.82
10	985	.375	13.34	22	904	.405	12.55
11	959	.360	14.05	23	885	.325	12.45
12	945	.370	14.92	24	1055	.295	12.37
General average						.372	

TABLE 13. AVERAGE WEIGHTS OF KERNELS FROM SIXTEEN EARS OF LOW-PROTEIN CORN.

Ear No.	Corn No.	Kernel, ave. wt.	Protein, per cent.	Ear No.	Corn No.	Kernel, ave. wt.	Protein, per cent.
1	1159	.385	9.02	9	1104	.410	7.76
2	1188	.355	8.83	10	1165	.355	7.85
3	1211	.305	8.66	11	1225	.280	8.32
4	1149	.290	8.62	12	1131	.310	8.58
5	1139	.345	8.57	13	1173	.335	8.63
6	1167	.340	8.29	14	1219	.360	8.82
7	1133	.360	7.85	15	1151	.350	8.90
8	1144	.275	7.50	16	1184	.335	8.95
General average						.337	

The weight of kernels is shown to vary from .290 to .470 gram in the high-protein corn, and from .275 to .410 gram in the low-protein corn, with a difference between the general averages of .035 gram. It is evident that the actual weight of the kernel gives very little, if any, indication as to the percentage of protein which it contains. This is illustrated in Figures 2 and 3.

Corn No.	945	1104
Protein, per cent.	**14.92**	**7.76**
Kernel, ave. wt.	**.370**	**.410**

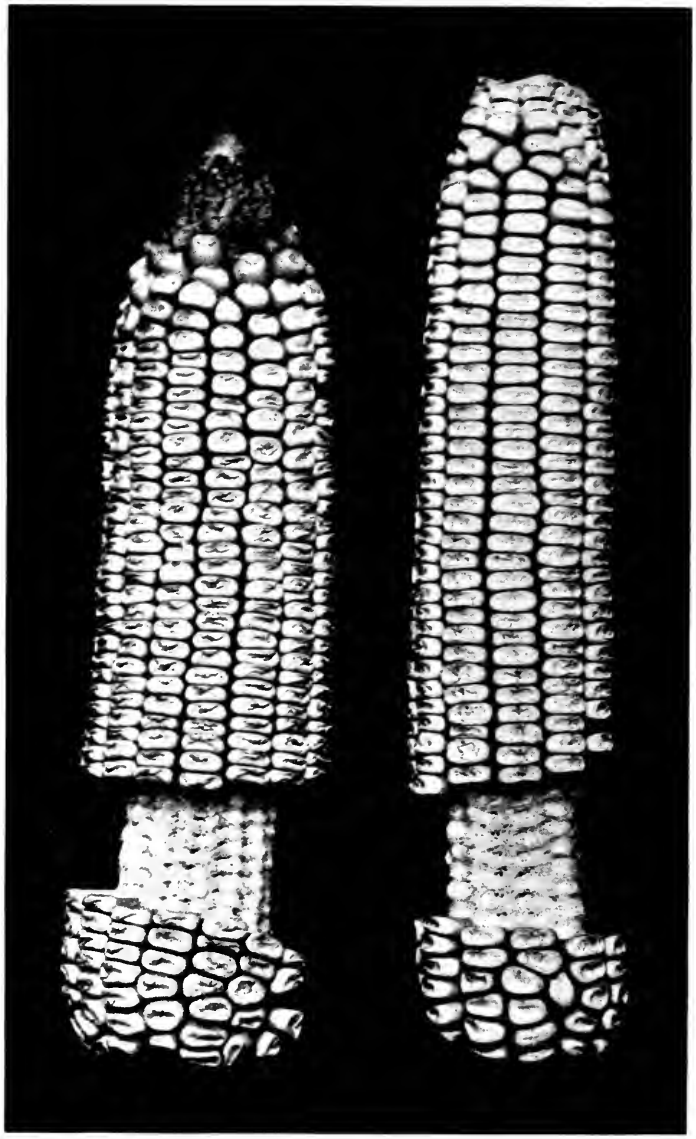

FIGURE 2.

Figure 2 shows high-protein corn, No. 945, containing 14.92 per cent. of protein, at the left, and at the right low-protein corn, No. 1104, with larger kernels but containing little more than half as much protein, 7.76 per cent.

Corn No.....	951	1149
Protein, per cent	14.25	8.62
Kernel, ave wt..	.410....	.290

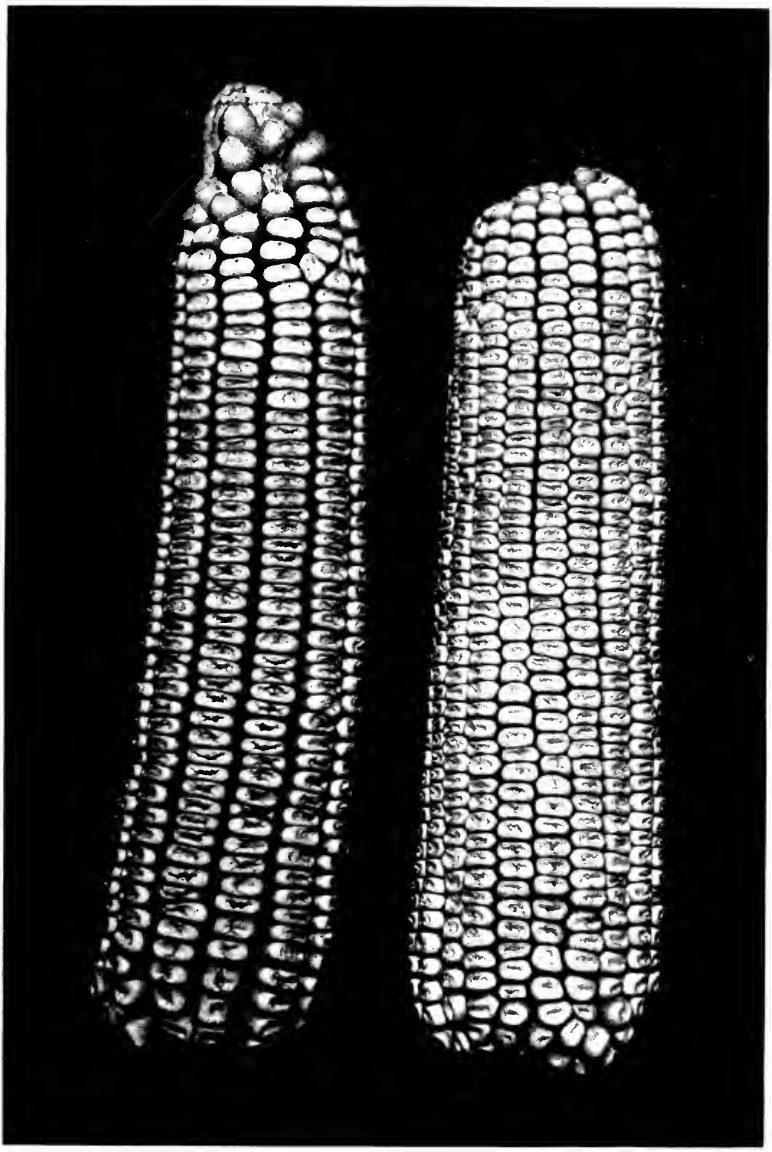

FIGURE 3.

Figure 3 shows corn containing 14.25 per cent. of protein, No. 951, at the left, and at the right No. 1149, with smaller kernels containing 8.62 per cent. of protein.

EXPERIMENTS TO INFLUENCE THE FAT CONTENT OF CORN.

From the lot of one hundred sixty-three ears of corn from the 1896 crop, the analyses of which are given in Table 1, seed was selected for the high-fat and low-fat plots for 1897, as already explained (see page 210). Tables 14 and 15 show the percentage of fat in the seed planted and in the crop produced.

TABLE 14. FAT IN CORN PLANTED AND HARVESTED ON HIGH-FAT PLOT IN 1897.

Plot row No.	Corn planted.		Corn harvested.		Plot row No.	Corn planted.		Corn harvested.	
	Corn No.	Fat, per cent.	Corn No.	Fat, per cent.		Corn No.	Fat, per cent.	Corn No.	Fat, per cent.
1	118	**5.02**			13	171	**5.75**	520	**4.99**
2	163	**5.09**			14	162	**5.61**	525	**4.84**
3	136	**5.10**	470	**4.43**	15	98	**5.51**	530	**5.23**
4	220	**5.23**	475	**4.74**	16	205	**5.36**	535	**4.70**
5	201	**5.22**	480	**4.77**	17	122	**5.25**	540	**4.47**
6	174	**5.22**	485	**4.65**	18	139	**5.23**	545	**4.81**
7	77	**5.24**	490	**4.50**	19	235	**5.27**	550	**4.38**
8	183	**5.46**	495	**4.53**	20	106	**5.21**	555	**4.80**
9	95	**5.51**	500	**4.98**	21	238	**5.20**	560	**4.58**
10	189	**5.63**	505	**4.75**	22	237	**5.13**	565	**4.46**
11	109	**5.65**	510	**5.40**	23	154	**5.02**		
12	236	**6.02**	515	**4.65**	24	144	**4.99**		
Plot averages.....							**5.33**	.....	**4.73**

TABLE 15. FAT IN CORN PLANTED AND HARVESTED ON LOW-FAT PLOT IN 1897.

Plot row No.	Corn planted.		Corn harvested.		Plot row No.	Corn harvested.		Corn planted.	
	Corn No.	Fat, per cent.	Corn No.	Fat, per cent.		Corn No.	Fat, per cent.	Corn No.	Fat, per cent.
1	149	**4.08**			7	182	**3.94**	595	**4.01**
1	152	**4.09**	570	**3.96**	8	123	**4.01**	600	**4.06**
3	150	**4.03**	575	**4.21**	9	228	**4.12**	605	**3.97**
4	192	**4.07**	580	**4.31**	10	133	**4.10**	610	**4.05**
5	196	**3.95**	585	**4.05**	11	212	**4.12**	615	**4.22**
6	166	**3.84**	590	**3.79**	12	156	**4.14**		
Plot averages.....							**4.04**	.....	**4.06**

These results indicate that the fat content of corn is influenced very markedly by selecting seed according to its percentage of fat. The average fat content of the seed for the high-fat plot is 5.33 per cent., while 4.04 is the average percentage in the seed for the low-fat plot. This shows an average difference in the seed for the two plots of

1.29 per cent. of fat. The difference between the average fat contents of the crops from the two plots is .67 per cent., the average from the high-fat plot being 4.73 and from the low-fat plot 4.06 per cent. of fat. There is a difference of .79 per cent. of fat between the averages of the two crops, if we consider only the central half of each plot. It is noteworthy that the lowest percentage of fat in the corn from any row of the high-fat plot, namely, 4.38 per cent. in row 19, is higher than the highest percentage obtained from any row in the low-fat plot.

It will be seen that samples were not taken from some of the outer rows in these plots, namely, rows 1, 2, 23, and 24 in the high-fat plot, and rows 1 and 12 in the low-fat plot. From all other rows sets of ten ears each were taken, the results here given being obtained by the analysis of the composite sample for each row.

From each set of ten ears from the 1897 crop, four ears were taken for individual analysis, a sample of three or four rows of kernels (lengthwise of the ear) being taken for this purpose. In these samples only fat and dry matter were determined. The system of numbering the samples was the same as that followed in the experiments with the protein content of corn, the multiple of five being given to the composite sample and the next four numbers to the samples of four single ears from the same row. Thus, the composite sample from row 3, high-fat plot, 1897, is numbered 470 (Table 14), and the four samples of individual ears from the same row are numbered 471, 472, 473, and 474 (Table 16).

TABLE 16. FAT IN SAMPLES OF EIGHTY EARS OF CORN GROWN ON HIGH-FAT PLOT IN 1897.

Corn No.	Fat, per cent.	Corn No.	Fat, per cent.	Corn No.	Fat, per cent.	Corn No.	Fat, per cent.	Corn No.	Fat, per cent.
471	4.44	491	4.85	511	5.44	531	5.04	551	4.31
472	4.79	492	4.38	512	5.45	532	4.82	552	4.33
473	4.42	493	4.93	513	5.49	533	4.98	553	4.24
474	4.59	494	4.97	514	5.39	534	5.27	554	4.33
476	4.84	496	4.26	516	4.63	536	4.97	556	4.93
477	4.82	497	4.59	517	5.26	537	4.50	557	4.68
478	5.39	498	4.76	518	4.81	538	4.92	558	4.92
479	4.40	499	4.45	519	4.44	539	4.83	559	5.12
481	5.04	501	5.45	521	4.98	541	4.78	561	4.41
482	4.87	502	4.95	522	4.22	542	3.60	562	4.62
483	4.46	503	4.64	523	4.91	543	4.91	563	4.95
484	5.07	504	4.77	524	5.68	544	5.02	564	4.23
486	5.03	506	4.91	526	4.70	546	5.20	566	4.39
487	4.20	507	4.69	527	5.43	547	5.00	567	4.20
488	4.72	508	5.04	528	5.12	548	4.90	568	5.05
489	4.86	509	4.20	529	4.68	549	4.81	569	4.42

TABLE 17. FAT IN SAMPLES OF FORTY EARS OF CORN GROWN ON LOW-FAT PLOT IN 1897.

Corn No.	Fat, per cent.	Corn No.	Fat, per cent.	Corn No.	Fat, per cent.	Corn No.	Fat, per cent.	Corn No.	Fat, per cent.
571	4.00	581	4 74	591	3.85	601	4 68	611	3 84
572	3.96	582	4.69	592	3.72	602	3.55	612	4.08
573	3.89	583	4.65	593	3 38	603	3 80	613	4.39
574	3.83	584	4.07	594	3.39	604	4.42	614	3.39
576	4.21	586	4 21	596	4.21	606	3 50	616	4 08
577	4 28	587	4.74	597	4.22	607	4.40	617	4 19
578	4.18	588	3.70	598	4 42	608	3.90	618	4 43
579	4.41	589	3 85	599	4.04	609	3.90	619	4.68

Eighty samples of single ears from the high-fat plot and forty from the low-fat plot were analyzed. The percentage of fat in the dry matter is given in Tables 16 and 17.

It will be remembered that extreme variations are common in the protein content of different ears of corn even when grown the same season, from seed of uniform protein content, and in practically the same soil. Such variations do not seem characteristic of the fat content. Of the eighty ears selected from the high-fat plot, only one contained less than 4.20 per cent. of fat, while 4.06 is the average percentage of fat in the corn from the low-fat plot. On the other hand no ear from the low-fat plot was found to contain above 4.74 per cent. of fat, although 60 per cent. of the ears from the high-fat plot contained above that percentage of fat, the maximum being 5.68 per cent.

For 1898 the seed for the high-fat plot was from corn which grew on the high-fat plot in 1897, twenty-four of the eighty ears whose fat content is shown in Table 16 being selected. For the low-fat seed twelve ears were selected from the forty ears whose percentage of fat is shown in Table 17, all of which were grown from low-fat seed in 1897. The system of planting the highest of the high-fat seed and the lowest of the low-fat seed in the middle rows of the respective plots was followed in 1898. Good crops of corn were grown, and, when harvested, sets of ten ears each were taken from each row, composite samples to represent each row being made, as before, by taking two rows of kernels from each of the ten ears.

Tables 18 and 19 give the percentage of fat in the composite samples and also in the seed planted in each row.

TABLE 18. FAT IN CORN PLANTED AND HARVESTED ON HIGH-FAT PLOT IN 1898.

Plot row No.	Corn planted.		Corn harvested.		Plot row No.	Corn planted.		Corn harvested.	
	Corn No.	Fat, per cent.	Corn No.	Fat, per cent.		Corn No.	Fat, per cent.	Corn No.	Fat, per cent.
1	521	4 98	1240	4.86	13	513	5 49	1360	5.21
2	533	4 98	1250	4 74	14	512	5.45	1370	5 44
3	486	5.03	1260	4.94	15	527	5 43	1380	5 48
4	531	5 04	1270	5.17	16	514	5 39	1390	5 26
5	568	5 05	1280	5 36	17	517	5.26	1400	5 55
6	528	5 12	1290	4 79	18	559	5 12	1410	5 23
7	546	5 20	1300	4 87	19	484	5 07	1420	5 06
8	534	5 27	1310	5.20	20	544	5 02	1430	4 89
9	478	5 39	1320	5 16	21	508	5.04	1440	5 00
10	511	5 44	1330	5.25	22	547	5.00	1450	5 10
11	501	5.45	1340	5 21	23	536	4.97	1460	5 05
12	524	5.68	1350	5 63	24	494	4.97	1470	5 21
Plot averages.....							5.20	.....	5.15

TABLE 19. FAT IN CORN PLANTED AND HARVESTED ON LOW-FAT PLOT IN 1898.

Plot row No.	Corn planted.		Corn harvested.		Plot row No.	Corn planted.		Corn harvested.	
	Corn No.	Fat, per cent.	Corn No.	Fat, per cent.		Corn No.	Fat, per cent.	Corn No.	Fat, per cent.
1	589	3.85	1480	3.97	7	593	3.38	1540	3.69
2	574	3.83	1490	4.32	8	606	3.50	1550	3.78
3	592	3.72	1500	4.08	9	588	3.70	1560	3.93
4	602	3.55	1510	3.99	10	603	3.80	1570	4.18
5	594	3.39	1520	3.81	11	611	3.84	1580	4.21
6	614	3.39	1530	3.81	12	591	3.85	1590	4.11
Plot averages.....							3.65	.....	3.99

The average fat content of the corn from the high-fat plot for 1898 is 5.15 per cent., while 3.99 is the average percentage of fat in the corn from the low-fat plot, making a difference of 1.16 per cent. between the averages, and the difference becomes 1.45 per cent. if we consider only the central half of each plot, or 1.56 per cent. if only the central third of each plot is considered. The effect of planting the seed in gradation as to fat content from the center rows to either side is decidedly noticeable in the crop. It is only necessary to take averages of the fat content of the composite samples from the high-fat plot in groups of four to obtain a regular gradation in the same order as tha of the seed. Thus,—

Corn from rows.	Fat, average per cent.
1- 4	**4.93**
5- 8	**5.06**
9-12	**5.31**
13-16	**5.35**
17-20	**5.18**
21-24	**5.09**

In the low-fat plot the percentages of fat in the composite samples from the single rows are in regular gradation, if we omit only the outside rows, Nos. 1 and 12. This may be seen in Table 19.

There is some indication of the influence of the season upon the fat content of corn, which becomes apparent by comparing the results obtained in the two different years 1897 and 1898 (see Table 20).

TABLE 20. AVERAGE PERCENTAGES OF FAT IN CORN PLANTED AND HARVESTED IN 1897 AND 1898

Season		1897.	1898.
High-fat plot.	Fat in corn planted	5.33	5.20
	Fat in corn harvested	4.73	5.15
	Difference	**.60**	**.05**
Low-fat plot.	Fat in corn planted	4.04	3.65
	Fat in corn harvested	4.06	3.99
	Difference	**.02**	**.34**

The season of 1897 seems to have favored the production of corn of low fat content, the average percentage of fat in the crop from the low-fat plot being but .02 per cent. higher than in the seed, while in the high-fat plot the crop is .60 per cent. below the seed in fat content. In 1898 the production of corn high in fat seems to have been favored, the fat content of the crop being only .05 per cent. below that of the seed in the high-fat plot and .34 above that of the seed in the low-fat plot.

In 1898 a third plot of ground for the study of the fat content of corn was planted. This is called the "Mixed-fat Plot," and was planted after the same plan as the mixed-protein plot. It contained fifty hills arranged in five rows of ten hills each. In each hill two kernels of high-fat corn were planted on one side and two of low fat content on the other. The special object in this work was, of course, to avoid the influence of soil differences. When the crop was harvested composite

samples were made of the corn from each side of each row, two rows of kernels from eight to ten ears being used for each composite sample. Table 21 shows the fat content of the seed and of the crop for each side of each row.

TABLE 21. FAT IN CORN PLANTED AND HARVESTED ON MIXED-FAT PLOT IN 1898.

Plot row No.	Corn planted.		Corn harvested.		Corn planted.		Corn harvested.	
	Corn No.	Fat, per cent.	Corn No.	Fat, per cent.	Corn No.	Fat, per cent.	Corn No.	Fat, per cent.
1	546	**5.20**	752	**4 66**	594	**3 39**	751	**3.60**
2	511	**5.44**	754	**4 87**	614	**3 39**	753	**3 86**
3	524	**5.68**	756	**5 38**	593	**3 38**	755	**4 13**
4	513	**5.49**	758	**5.14**	606	**3 50**	757	**4 20**
5	527	**5 43**	760	**5.35**	588	**3 70**	759	**4 06**
Plot averages...				**5 08**	.....			**3 97**

The difference between the average fat content of the corn from high-fat seed and that from low-fat seed is 1.11 per cent. The lowest fat content of any composite sample from high-fat seed is 4.66 per cent., and 4.20 is the highest percentage of fat in a composite sample of corn from low-fat seed.

From the mixed-fat plot twenty-seven pairs of ears were taken from twenty-seven hills, one ear in each pair having grown from high-fat seed and the other ear from low-fat seed. Table 22 gives the fat content in the corn from each of these ears.

TABLE 22. FAT IN CORN FROM FIFTY-FOUR EARS GROWN ON THE MIXED-FAT PLOT IN 1898.

Hill No.	From high-fat seed.		From low-fat seed.		Hill No.	From high-fat seed.		From low-fat seed.	
	Corn No.	Fat, per cent.	Corn No	Fat, per cent.		Corn No.	Fat, per cent	Corn No.	Fat, per cent.
1	762	**4.05**	761	**3.82**	14	788	**5.03**	787	**4.08**
2	764	**4.42**	763	**3.62**	15	790	**5.57**	789	**3.57**
3	766	**4.65**	765	**3.03**	16	792	**5.32**	791	**4.69**
4	768	**4.90**	767	**3.92**	17	794	**5.75**	793	**3.96**
5	770	**5.16**	769	**3.94**	18	796	**4.95**	795	**4.64**
6	772	**5.06**	771	**3.99**	19	798	**4.79**	797	**4.30**
7	774	**5.13**	773	**4.15**	20	800	**4.59**	799	**4.33**
8	776	**4.95**	775	**3.75**	21	802	**5.56**	801	**3.77**
9	778	**5.59**	777	**3.60**	22	804	**5.34**	803	**4.17**
10	780	**4.10**	779	**4.04**	23	806	**4.92**	805	**4.50**
11	782	**4.49**	781	**3.56**	24	808	**5.91**	807	**3.58**
12	784	**5.25**	783	**4.26**	25	810	**5.86**	809	**4.55**
13	786	**5.65**	785	**4.15**	26	812	**4.59**	811	**3.96**
					27	814	**5.02**	813	**4.23**
Averages.....							**5.06**	.....	**4.01**

The average percentage of fat in the twenty-seven ears from high-fat seed is 5.06, while 4.01 per cent. is the average fat content of the same number of ears from low-fat seed. It is interesting to note that in the twenty-seven hills there is no instance where the ear of corn from high-fat seed does not contain more fat than the ear grown from low-fat seed in the same hill. The difference in fat content between ears in the same hill varies from .06 per cent. in hill No. 10 to 2.33 per cent. in hill No. 24.

The ear which grew from low-fat seed in hill No. 3 has the lowest fat content, 3.03 per cent., of any ear of corn which has been analyzed in these experiments. The maximum fat content which has been found in an ear of Burr's White corn up to the present time is 6.71 per cent. It seems reasonable to suppose that these limits may be reached again or exceeded, and possibly by corn in larger amounts than single ears. The experiments upon the fat content of corn are summarized at the end of this bulletin.

The fact that the fat, or oil, of the corn kernel is contained almost entirely in the germ (see Bulletin No. **53,** pages 139 and 140) suggested to the writer the possibility of selecting corn, of high or low fat content by mechanical examination of the kernel and judging as to the quantity of germ compared with the remainder of the kernel. It was found that the method is possible and rather more satisfactory than the method (already described) of judging the protein content of the corn kernel by mechanical examination, as it is less complicated than the latter.

Figure 4 (made from a photograph taken with a magnification of three diameters) illustrates the difference in corn kernels of about the same size but of very different fat content. The cross sections, shown at the top, were made by cutting off about one-fifth of the kernel from the tip end. In the longitudinal sections the tip end of the kernel points downward to the left. The sections and kernel shown at the left are from an ear of corn (No. 1338) which contains 6.08 per cent. of fat. Those at the right are from an ear (No. 1512) containing 3.64 per cent. of fat.

It will be seen that the germ is larger in the high-fat corn and that it extends nearly the entire length of the kernel, while in the low-fat corn the germ is small and about two-thirds as long as the kernel. Aside from the rather slight difference in the size of the depressions, the general appearance of the whole kernels is about the same whether they are rich or poor in fat content. This is true also of ears with kernels of about the same size, as may be seen from Figure 5 which illustrates the two ears from which were taken the kernels shown in Figure 4, the high-fat ear being at the left and the low-fat at the right.

Corn No.....	1338...	1512
Fat, per cent....	**6.08**.....	**3.64**

FIGURE 4.

There is apparently some tendency toward large kernels with ears of corn having a low fat content, and *vice versa*, indicating that the change in the percentage of fat is brought about, in part, at least, by the absolute increase or decrease of carbohydrates. In other words, in selecting seed with a low percentage of fat, as determined by chemical analysis, the ears chosen will have a tendency not only to small germs but to large kernels. This is illustrated by Tables 23 and 24, which give the average weights in grams of the air-dry kernels from twenty-eight different ears which were used in 1899 as seed for high-fat and low-fat plots. The percentage of fat in the dry matter is also given.

The average weight of the high-fat kernels is .345 gram, while the

Corn No	1338	1512
Fat, per cent	**6.08**	**3.64**
Kernel, av. wt	**.335**	**.310**

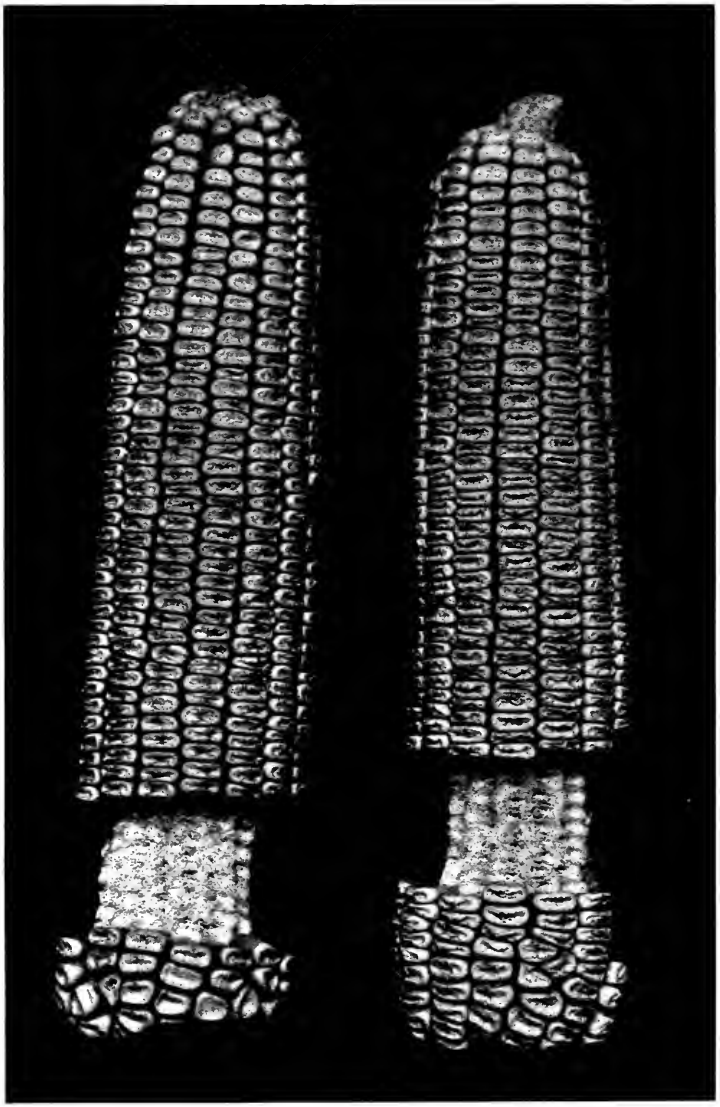

FIGURE 5.

low-fat kernels average .420 gram. However, there are wide variations from this apparent tendency.

TABLE 23. AVERAGE WEIGHTS OF KERNELS FROM TWELVE EARS OF HIGH-FAT CORN.

Ear No.	Corn No.	Kernel, ave. wt.	Fat, per cent.	Ear No.	Corn No.	Kernel, ave. wt.	Fat, per cent.
1	1413	.325	5.83	7	1354	.295	6.49
2	1342	.370	5.90	8	1476	.400	6.34
3	1338	.335	6.08	9	1308	.315	6.09
4	1314	.345	6.28	10	1276	.405	5.90
5	1389	.305	6.47	11	1379	.340	5.89
6	1352	.340	6.71	12	1259	.370	5.82
General average...						.345	

TABLE 24. AVERAGE WEIGHTS OF KERNELS FROM SIXTEEN EARS OF LOW-FAT CORN.

Ear No.	Corn No.	Kernel, ave. wt.	Fat, per cent.	Ear No.	Corn No.	Kernel, ave. wt.	Fat, per cent.
1	1521	.490	3.64	9	1522	.525	3.27
2	1559	.430	3.63	10	1531	.380	3.33
3	1564	.500	3.58	11	1545	.470	3.35
4	1538	.370	3.56	12	1486	.430	3.39
5	1504	.390	3.38	13	1557	.500	3.56
6	1539	.355	3.34	14	1543	.410	3.59
7	1516	.390	3.32	15	1512	.310	3.64
8	1529	.320	3.22	16	1548	.450	3.65
General Average						.420	

While the tendency of high-fat corn to small kernels and of low-fat corn to large kernels aids, in a way, in the selection of corn of high or low fat content, the difficulty of judging the percentage of fat by the comparative sizes of germ and kernel is greatly increased by the wide variations in the size of kernels. With kernels of approximately the same size, and with germs of similar shape, as those shown in Figure 4, it is an easy matter to distinguish between high-fat corn and low-fat corn; but frequently a large kernel of low fat content will have a larger germ than a smaller kernel of a higher percentage of fat; or the germs in the kernels from one ear may be short and thick, and from another ear they may be long and slender, the difficulties in the way of forming accurate judgment being thus increased.

To obtain exact data as to the relation between the percentage of fat and the percentage of germ in the corn kernel, the germs were removed from a large number of kernels, the weight of the whole kernel and also of the separated germ being determined and reported on the basis of dry matter, having been dried in hydrogen before being

weighed. It was found that after soaking corn kernels in hot water for about thirty minutes the germs are easily removed in the entire state and quite free from other portions of the kernel.

In Table 25 are given the results from eighty kernels of corn, ten kernels being taken from each of eight different ears. No. 1354 represents an ear of high fat content, 6.49 per cent., and small kernels, average weight .2652 gram. The germs average .0374 gram in weight, and amount to 14.11 per cent. of the whole kernel. Corn No. 1564 contains 3.58 per cent. of fat. The kernels average .4631 gram and the germs .0421 gram in weight. The germs amount to only 9.10 per cent. of the whole kernel although the average weight of the germ is considerably more than in No. 1354. This ear, No. 1564, illustrates a relatively low fat content produced by an absolute increase in carbohydrates. In corn No. 1352, containing 6.71 per cent. fat and No. 1529, containing 3.22 per cent. fat, the kernels are approximately uniform in size, the former being .3013 and the latter .3181 gram in average weight. The germs in the high-fat ear amount to 12.40 per

TABLE 25. WEIGHTS OF CORN KERNELS WITH WEIGHT AND PERCENTAGE OF GERM.

Kernel No	Kernel, wt. gms.	Germ, wt. gms.	Germ, per cent.	Kernel No.	Kernel, wt. gms.	Germ, wt. gms.	Germ, per cent.
Corn No. 1354.—Fat = 6.49 per cent.				Corn No. 1564.—Fat = 3.58 per cent			
1	.2611	.0411	**15.74**	1	.4478	.0418	**9.33**
2	.2718	.0385	**14.16**	2	.4428	.0446	**10.07**
3	.2633	.0370	**14.05**	3	.4402	.0402	**9.13**
4	.2789	.0382	**13.70**	4	.4943	.0420	**8.50**
5	.2427	.0347	**14.30**	5	.4205	.0405	**9 63**
6	.2859	.0372	**13.01**	6	.4714	.0439	**9.31**
7	.2642	.0362	**13.70**	7	.4968	.0436	**8.78**
8	.2595	.0329	**12.68**	8	.4398	.0361	**8.21**
9	.2567	.0359	**13.99**	9	.4581	.0446	**9.74**
10	.2680	.0422	**15.75**	10	.5188	.0432	**8 33**
Averages,	.2652	.0374	**14.11**	Averages,	.4631	.0421	**9.10**
Corn No. 1352.—Fat = 6.71 per cent.				Corn No. 1529.—Fat = 3.22 per cent.			
1	.3113	.0391	**12.56**	1	.2859	.0250	**8.74**
2	.2872	.0360	**12.53**	2	.2882	.0237	**8.22**
3	.2864	.0340	**11.87**	3	.3533	.0297	**8.41**
4	.2821	.0374	**13.26**	4	.3135	.0265	**8.45**
5	.2667	.0360	**13.50**	5	.3277	.0273	**8.33**
6	.3694	.0442	**11.97**	6	.3417	.0310	**9.07**
7	.3434	.0414	**12.06**	7	.2918	.0257	**8.81**
8	.2682	.0300	**11.18**	8	.3178	.0276	**8.68**
9	.3116	.0402	**12.90**	9	.3273	.0278	**8.49**
10	.2870	.0348	**12.13**	10	.3338	.0280	**8.39**
Averages,	.3013	.0373	**12.40**	Averages,	.3181	.0272	**8.56**

TABLE 25.—*Continued.*

Kernel No.	Kernel, wt. gms.	Germ, wt. gms.	Germ, per cent.
Corn No. 1338.— Fat = 6.08 per cent.			
1	.3268	.0373	**11.41**
2	.3229	.0385	**11.92**
3	.3031	.0308	**10.16**
4	.3122	.0400	**12.81**
5	.3025	.0349	**11.54**
6	.3018	.0384	**12.72**
7	.2963	.0363	**12.25**
8	.3095	.0361	**11.66**
9	.2871	.0395	**13.76**
10	.3424	.0407	**11.89**
Averages	.3105	.0373	**12.01**
Corn No. 1259.— Fat = 5 82 per cent.			
1	.2719	.0371	**13.64**
2	.3172	.0390	**12.30**
3	.3571	.0468	**13.11**
4	.3602	.0514	**14.27**
5	.3446	.0482	**13.99**
6	.3786	.0455	**12.02**
7	.3453	.0450	**13.03**
8	.3206	.0454	**14.16**
9	.3927	.0472	**12.02**
10	.3304	.0476	**14.41**
Averages	.3419	.0453	**13.30**

Kernel No.	Kernel, wt. gms.	Germ, wt. gms.	Germ, per cent.
Corn No. 1512.— Fat = 3.64 per cent.			
1	.2813	.0258	**9.17**
2	.3156	.0259	**8.21**
3	.2674	.0206	**7.70**
4	.2740	.0229	**8.36**
5	.2805	.0250	**8.91**
6	.2935	.0232	**7.90**
7	.3223	.0251	**7.79**
8	.2752	.0238	**8.65**
9	.3008	.0233	**7.75**
10	.2664	.0222	**8.33**
Averages	.2877	.0238	**8.28**
Corn No. 1516.— Fat = 3.32 per cent.			
1	.3969	.0338	**8.52**
2	.3293	.0246	**7.47**
3	.3586	.0364	**10.15**
4	.3434	.0318	**9.26**
5	.3401	.0296	**8.70**
6	.3348	.0283	**8.45**
7	.3317	.0272	**8.20**
8	.3096	.0240	**7.75**
9	.3843	.0340	**8.85**
10	.3733	.0373	**9.99**
Averages	.3502	.0307	**8.73**

cent. of the whole kernels, and to only 8.56 per cent. in the low-fat ear. This difference is due to the absolute difference in the size of the germs, the germs from the high-fat kernels being .0373 gram and from the low-fat kernels only .0272 gram average weight. Nos. 1338 and 1512 are the same ears as are shown in Figure 5, and from which the kernels shown in Figure 4 were taken. The fat content is 6.08 and 3.64 per cent. and the percentage of germ 12.01 and 8.28, respectively. Nos. 1259 and 1516 are ears with medium sized kernels, the average weight being about the same from each ear. The former contains 5.82 per cent. of fat and 13.30 per cent. of germ, the latter 3.32 per cent. of fat and 8.73 per cent. of germ, as an average.

It will be seen that the general relation between the percentage of fat and the percentage of germ in the corn kernel is clearly established. Of course there are minor individual differences among the kernels from the same ear, and it is also noted that there is a difference in different ears as to the relation between fat content and germ content.

For example, corn No. 1354 contains 6.49 per cent. of fat and 14.11 per cent. of germ; while corn No. 1352 contains a higher percentage of fat but a lower percentage of germ. Again the corn of lowest fat content is not quite the lowest in percentage of germ. These minor differences are perhaps due in part, to the varying percentage of fat in the remainder of the kernel, although the variation in the percentage of fat in the germ is doubtless the chief factor in producing such differences. For example, Voorhees found 26.65 per cent. of fat in the germs of the corn kernel, while Balland found 39.85 per cent. (See Bulletin No. **53**, page 140).

The method of selecting corn of high or low fat content by mechanical examination is similar to that described under the work on the protein content of the corn kernel, excepting that the size of the germ alone as compared with the remainder of the kernel is considered. Judgment is formed by examining with the naked eye the cross sections and longitudinal sections of a few kernels from an ear.

Table 26 shows the results obtained in picking out corn by mechanical examination from a lot which contained corn of only very high or of very low fat content.

TABLE 26. ACTUAL FAT CONTENT OF CORN SEPARATED BY MECHANICAL EXAMINATION.

Ear No.	Corn selected for		Ear No.	Corn selected for		Ear No.	Corn selected for	
	High fat.	Low fat.		High fat.	Low fat.		High fat.	Low fat.
	Per cent.	Per cent.		Per cent.	Per cent.		Per cent.	Per cent.
1	**5.90**	**3.56**	6	**6.71**	**3.65**	11	**5.80**	**3.67**
2	**6.08**	**3.59**	7	**6.49**	**3.22**	12	**6.09**	**3.50**
3	**6.28**	**3.63**	8	**5.94**	**3.67**	13	**5.82**	**3.63**
4	**3.65**	**3.58**	9	**5.87**	**3.27**	14	**5.90**	**3.64**
5	**6.47**	**3.32**	10	**6.34**	**3.39**	15	**5.89**	**3.64**

In picking out fifteen ears for high-fat corn and fifteen ears for low-fat corn but one error was made, namely, the fourth ear selected for high-fat corn which really contained a low percentage of fat.

To make a more practical test of the method a miscellaneous lot of corn was examined,—in all two hundred seventy-two ears, which varied in fat content from about 3.60 to 5.80 per cent. Twelve ears of very high fat content and sixteen ears of very low fat content had been taken from this lot and used for seed in 1899 (see Tables 23 and 24), otherwise the results would no doubt have been more marked than they are.

From the lot of two hundred seventy-two ears, by mechanical

examination eighteen ears were selected which appeared to possess a comparatively high fat content, and at the same time thirty ears apparently low in fat were selected. Tables 27 and 28 give the results.

TABLE 27. FAT CONTENT OF EIGHTEEN EARS SELECTED BY MECHANICAL EXAMINATION FOR HIGH-FAT CORN.

Ear No.	Fat, per cent.	Ear No.	Fat, per cent.	Ear No.	Fat, per cent.	Ear No.	Fat, per cent.	Ear No.	Fat, per cent.
1	**4.94**	5	**5.23**	9	**5.22**	13	**5.27**	17	**4.97**
2	**4.30**	6	**5.58**	10	**5.33**	14	**5.12**	18	**5.21**
3	**5.43**	7	**5.06**	11	**5.55**	15	**5.73**		
4	**5.64**	8	**5.26**	12	**4.99**	16	**5.43**		
Average									**5.24**

TABLE 28. FAT CONTENT OF THIRTY EARS SELECTED BY MECHANICAL EXAMINATION FOR LOW FAT CORN.

Ear No.	Fat, per cent.	Ear No.	Fat, per cent.	Ear No.	Fat, per cent.	Ear No.	Fat, per cent.	Ear No.	Fat, per cent.
1	**4.01**	7	**4.07**	13	**3.73**	19	**4.52**	25	**4.09**
2	**4.11**	8	**4.20**	14	**3.76**	20	**4.29**	26	**4.27**
3	**3.64**	9	**3.91**	15	**5.21**	21	**3.81**	27	**4.02**
4	**3.67**	10	**4.85**	16	**3.63**	22	**4.39**	28	**3.87**
5	**4.52**	11	**4.35**	17	**4.02**	23	**4.43**	29	**4.00**
6	**3.66**	12	**4.52**	18	**4.55**	24	**3.80**	30	**3.98**
Average									**4.13**

The average fat content of the ears selected for high-fat corn is 5.24 per cent., while 4.13 is the average of that selected for low-fat corn.

TABLE 29. WEIGHT OF CORN KERNELS WITH WEIGHT AND PERCENTAGE OF GERM.

Ear 2. Table 27.—Fat = 4 30 per cent.

Kernel No.	Kernel, wt. gms.	Germ, wt. gms.	Germ, per cent.
1	.3580	.0346	**9.66**
2	.3670	.0362	**9.86**
3	.2939	.0277	**9.42**
4	.2841	.0306	**10.77**
5	.2969	.0262	**8.82**
6	.3054	.0326	**10.67**
7	.3156	.0304	**9.63**
8	.2866	.0284	**9.91**
9	.3452	.0354	**10.25**
10	.3053	.0280	**9.17**
Averages	.3158	.0310	**9.82**

Ear 15. Table 28.— Fat = 5 21 per cent.

Kernel No.	Kernel, wt. gms.	Germ, wt. gms.	Germ, per cent.
1	.4014	.0450	**11.21**
2	.3674	.0348	**9.47**
3	.3975	.0463	**11.65**
4	.4392	.0410	**9.33**
5	.4571	.0539	**11.79**
6	.3541	.0442	**12.48**
7	.3968	.0377	**9.50**
8	.4225	.0463	**10.96**
9	.3850	.0497	**12.91**
10	.4096	.0464	**11.33**
Averages	.4031	.0445	**11.06**

If we omit ear No. 2 in Table 27 and ear No. 15 in Table 28, the lowest percentage of fat in the ears selected for high fat content is higher than the highest percentage in the low-fat selection.

Ten kernels from each of the two ears just mentioned were taken, and the exact percentage of germ in each kernel determined, in order to ascertain whether these ears were selected because of incorrect judgment or were exceptions to the general rule that the percentage of fat varies with the percentage of germ in the corn kernel. The results are given in Table 29.

While some variations in individual kernels from the same ear exist, it is seen that the corn of 4.30 per cent. fat contains 9.82 per cent. of germ, while the ear with 5.21 per cent fat contains 11.06 per cent. of germ, in the kernel as an average, showing that the judgment was incorrect, having been formed possibly from insufficient data.

SUMMARY OF EXPERIMENTS TO IMPROVE THE CHEMICAL COMPOSITION OF THE CORN KERNEL.

All results thus far obtained indicate that it is possible to influence the composition of corn; that by proper selection of seed any of its principal constituents, protein, fat, or carbohydrates, may be increased or decreased.

In 1897 a plot of corn planted with seed containing a high percentage of protein produced a crop containing 11.10 per cent. of protein, while 10.55 was the percentage contained in a crop grown from seed of low protein content. By considering only the central half of each plot, the crop from seed high in protein shows 11.12 per cent. of protein, and the crop from low-protein seed shows 10.21 per cent.

In 1898 the crop of corn from the seed of high protein content contained 11.05 per cent. of protein, while that from low-protein seed contained 10.55 per cent. If only the central half of each plot is considered the results show 11.17 per cent. and 10.47 per cent. of protein in the corn from the respective seed.

The average protein content of twenty-two ears of corn grown in twenty-two different hills from high-protein seed was 11.11 per cent., while 10.15 was the average percentage of protein contained in twenty-two other ears grown in the same twenty-two hills from low-protein seed.

Fifty hills of corn were planted with two kernels of high-protein seed and two kernels of low-protein seed in each hill. The average protein content of the crop grown from high-protein seed was 11.71 per cent., while 10.46 was the average percentage in the crop from the low-protein seed.

In the six tests the selection of seed corn of high and low protein

content has produced differences in the crops varying from .50 to 1.25 per cent. of protein.

In 1897 a plot of corn planted with seed of high fat content produced a crop containing 4.73 per cent. of fat, while the crop produced on a plot planted with seed of low fat content contained an average of 4.06 per cent. Considering only the central half of each plot the crop from the high-fat seed contained 4.82 per cent. of fat, while that from low-fat seed contained 4.03 per cent.

In 1898 the high-fat seed produced a crop containing 5.15 per cent. of fat and the crop from low-fat seed contained only 3.99 per cent. Again by considering only the central half of each plot the percentages of fat in the crops are found to be 5.29 and 3.84, respectively.

The average fat content of twenty-seven ears grown in 1898 in twenty-seven different hills from high-fat seed was 5.06 per cent., while 4.01 was the average percentage of fat contained in twenty-seven other ears grown in the same twenty-seven hills from seed of low fat content.

Fifty hills were planted with two kernels of high-fat seed and two kernels of low-fat seed in each hill. The average fat content of the crop produced from the high-fat seed was 5.08 per cent., while 3.97 was the average percentage in the crop from low-fat seed.

In the six tests the selection of seed of high and low fat content has produced differences in the crops varying from .67 to 1.45 per cent. of fat.

The fat content of corn is even more susceptible to the influence of seed selection than is the protein content, doubtless due to the fact that the primary materials from which fat is manufactured, namely, carbon dioxid and water, are usually furnished to the plant in unlimited supply, while the formation of protein is essentially dependent upon the supply of available nitrogen in the soil.

As the percentage of carbohydrates (principally starch in corn) varies inversely with the combined percentages of protein and fat it follows that the carbohydrates are increased in percentage whenever the combined percentage of protein and fat is decreased, and *vice versa*.

It has been found that the protein content of corn varies chiefly with the proportion of glutenous layer in the kernel and that by mechanical examination of corn kernels this variation in the proportion of glutenous layer can easily be observed with the naked eye.

It has also been found that the fat content of corn varies quite uniformly with the proportion of germ in the kernel and that by mechanical examination this variation in the relative amount of germ in the whole kernel can also be observed with the eye.

By actual trial it has been found both possible and practicable to

select corn by mechanical examination with either high or low content of protein, fat, or starch.

While further investigations are necessary, and are in progress, to determine more accurately the best methods and more definitely the possibilities of improvement in the chemical composition of corn, it is here stated, tentatively, that essentially by the methods reported in this bulletin any corn grower will be able to select seed and to breed corn to increase or to decrease the percentage of any one of its three principal chemical constituents.

All experiments reported in this bulletin have been carried on with the one variety of corn, namely, Burr's White. Of course, it is not believed that Burr's White is the best variety for improvement in corn in every one of the several important lines. Indeed it seems highly probable that one variety of corn will be found best adapted to but one line of improvement. We have in progress chemical studies of other varieties of corn, and a considerable amount of data and information has been already acquired, but it is reserved, pending further investigations, for future publication, the special object of this bulletin being to give the data, thus far obtained, indicating the possibility and establishing the fact that the corn kernel may be improved in chemical composition.

It may be stated that improvement in the composition of other parts of the corn plant is under consideration by this Station. Plans are made also to investigate other questions relating to this general subject; such as the effect of changes in the chemical composition of corn upon its digestibility, vitality, yield, etc.

The results obtained in our investigations to improve the composition of corn have suggested the possibility of improving other grains by somewhat similar methods. It seems not improbable that the different grains or kernels produced in a single head of wheat, oats, barley, etc., may be found to be approximately uniform in composition. If so, a method is thus offered for selecting seed according to its chemical composition.

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